US009319767B2

(12) **United States Patent**
**Sakaguchi et al.**

(10) **Patent No.: US 9,319,767 B2**
(45) **Date of Patent: Apr. 19, 2016**

(54) **EARPHONE**

(71) Applicant: **Panasonic Intellectual Property Management Co., Ltd.**, Osaka (JP)

(72) Inventors: **Atsushi Sakaguchi**, Osaka (JP); **Shuji Saiki**, Nara (JP); **Toshiyuki Matsumura**, Osaka (JP); **Sawako Kano**, Hyogo (JP); **Akiko Fujise**, Osaka (JP)

(73) Assignee: **PANASONIC INTELLECTUAL PROPERTY MANAGEMENT CO., LTD.**, Osaka (JP)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/003,892**

(22) PCT Filed: **Jan. 29, 2013**

(86) PCT No.: **PCT/JP2013/000471**
§ 371 (c)(1),
(2) Date: **Sep. 9, 2013**

(87) PCT Pub. No.: **WO2013/114864**
PCT Pub. Date: **Aug. 8, 2013**

(65) **Prior Publication Data**

US 2014/0056455 A1 Feb. 27, 2014

(30) **Foreign Application Priority Data**

Jan. 30, 2012 (JP) ................................ 2012-016760

(51) **Int. Cl.**

***H04R 25/00*** (2006.01)
***H04R 1/10*** (2006.01)
***H04R 1/28*** (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ................ ***H04R 1/10*** (2013.01); ***H04R 1/2811*** (2013.01); ***H04R 25/02*** (2013.01); ***H04R 25/48*** (2013.01); *H04R 1/1016* (2013.01); *H04R 9/027* (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,058,688 A * 11/1977 Nishimura et al. ........... 381/372
4,742,887 A * 5/1988 Yamagishi .................... 181/129
(Continued)

FOREIGN PATENT DOCUMENTS

JP 62-141293 9/1987
JP 11-308685 11/1999
(Continued)

OTHER PUBLICATIONS

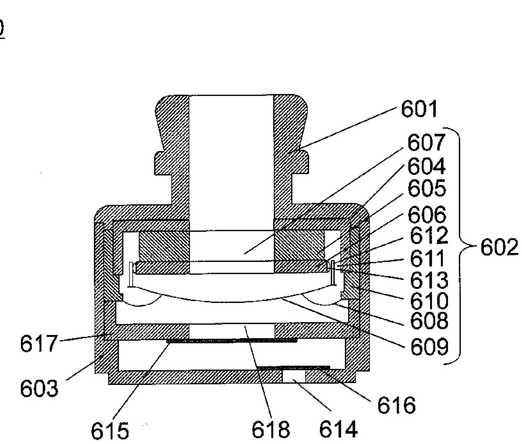
International Search Report mailed Mar. 26, 2013 in International (PCT) Application No. PCT/JP2013/000471.
(Continued)

*Primary Examiner* — Davetta W Goins
*Assistant Examiner* — Phylesha Dabney
(74) *Attorney, Agent, or Firm* — Wenderoth, Lind & Ponack, L.L.P

(57) **ABSTRACT**

An earphone includes: a loudspeaker unit; a sound conductive tube which is connected to a front surface having a diaphragm included in the loudspeaker unit, and has a hole through which a sound generated from the loudspeaker unit is emitted; a housing which is connected to a back surface of the loudspeaker unit so that a space is formed between the housing and the back surface of the loudspeaker unit, and has a first air hole connecting the space to external air; a first braking part which closes a sound hole of the loudspeaker unit; and a second braking part which closes the first air hole.

**6 Claims, 15 Drawing Sheets**



(51) **Int. Cl.**
***H04R 25/02*** (2006.01)
*H04R 9/02* (2006.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS


| | | | | |
|---|---|---|---|---|
| 7,149,323 | B2 * | 12/2006 | Yamagishi | 381/415 |
| 7,447,308 | B2 * | 11/2008 | Tsai | 379/430 |
| 8,611,581 | B2 * | 12/2013 | Matsuo et al. | 381/380 |
| 8,670,586 | B1 * | 3/2014 | Boyle et al. | 381/370 |
| 8,885,866 | B2 * | 11/2014 | Sakaguchi et al. | 381/382 |
| 2006/0093180 | A1 * | 5/2006 | Kim | 381/412 |
| 2007/0189569 | A1 * | 8/2007 | Haapapuro | H04R 1/1016 381/380 |
| 2007/0201717 | A1 * | 8/2007 | Dyer et al. | 381/380 |
| 2009/0285437 | A1 * | 11/2009 | Takigawa et al. | 381/380 |
| 2010/0166245 | A1 | 7/2010 | Takigawa et al. | |
| 2014/0056455 | A1 * | 2/2014 | Sakaguchi et al. | 381/328 |
| 2014/0348372 | A1 * | 11/2014 | Seo et al. | 381/380 |

FOREIGN PATENT DOCUMENTS

| | | |
|---|---|---|
| JP | 2008-283398 | 11/2008 |
| JP | 2010-4513 | 1/2010 |
| JP | 2010-283643 | 12/2010 |
| JP | 2011-082702 | 4/2011 |
| JP | 2011-182201 | 9/2011 |
| WO | 97/47117 | 12/1997 |

OTHER PUBLICATIONS

Extended European Search Report issued Dec. 22, 2014 in corresponding European Patent Application No. 13744295.0.


* cited by examiner

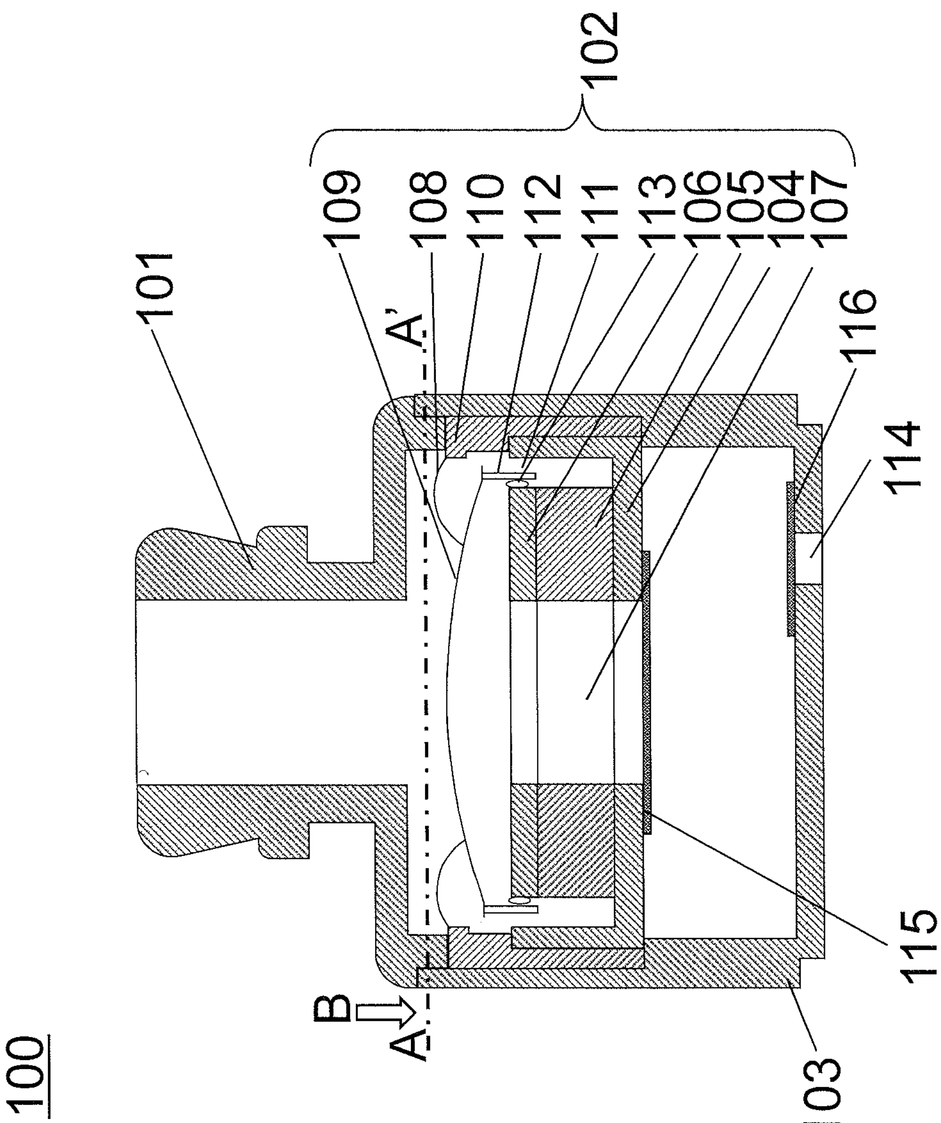
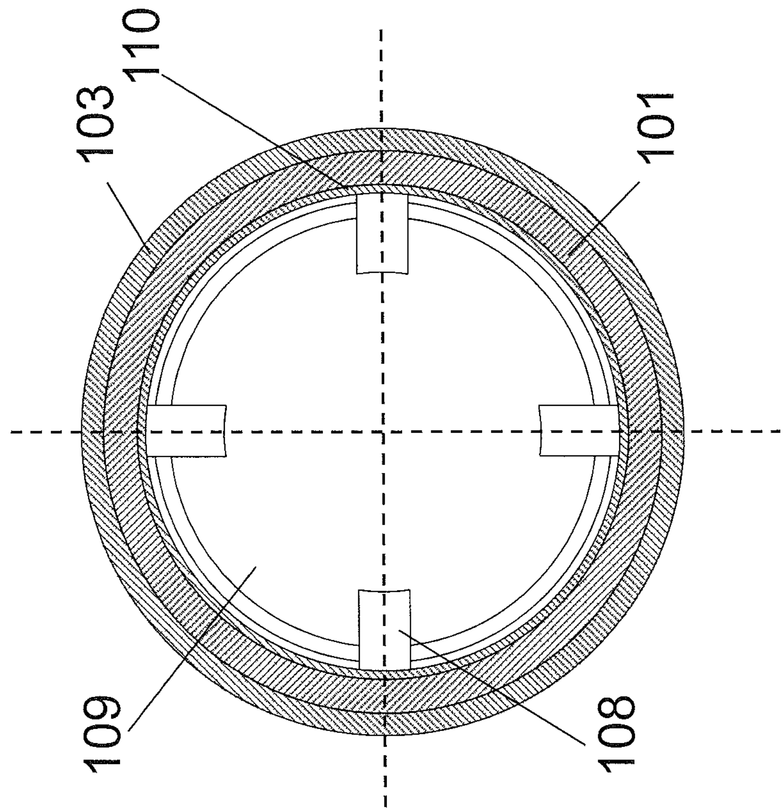

100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
A
A'
B

FIG. 1A




100

FIG. 1B

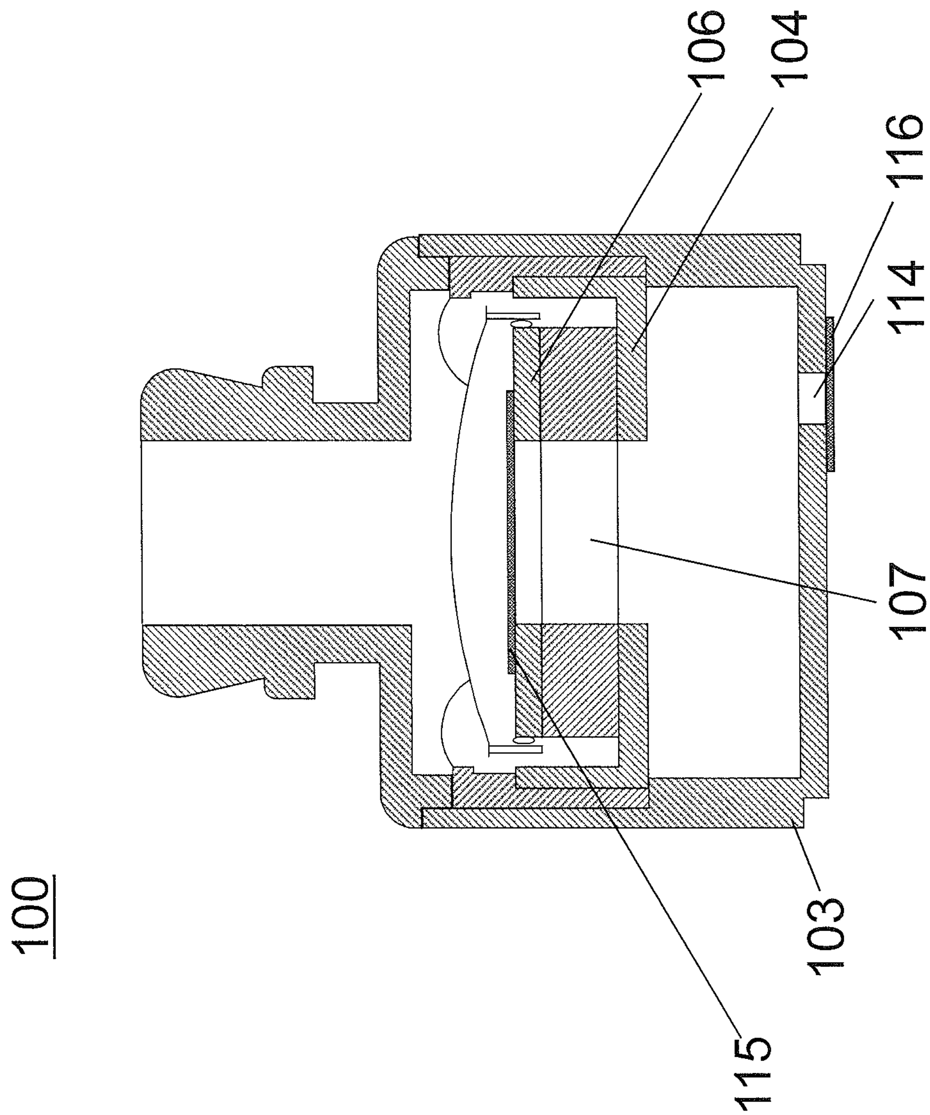



FIG. 2

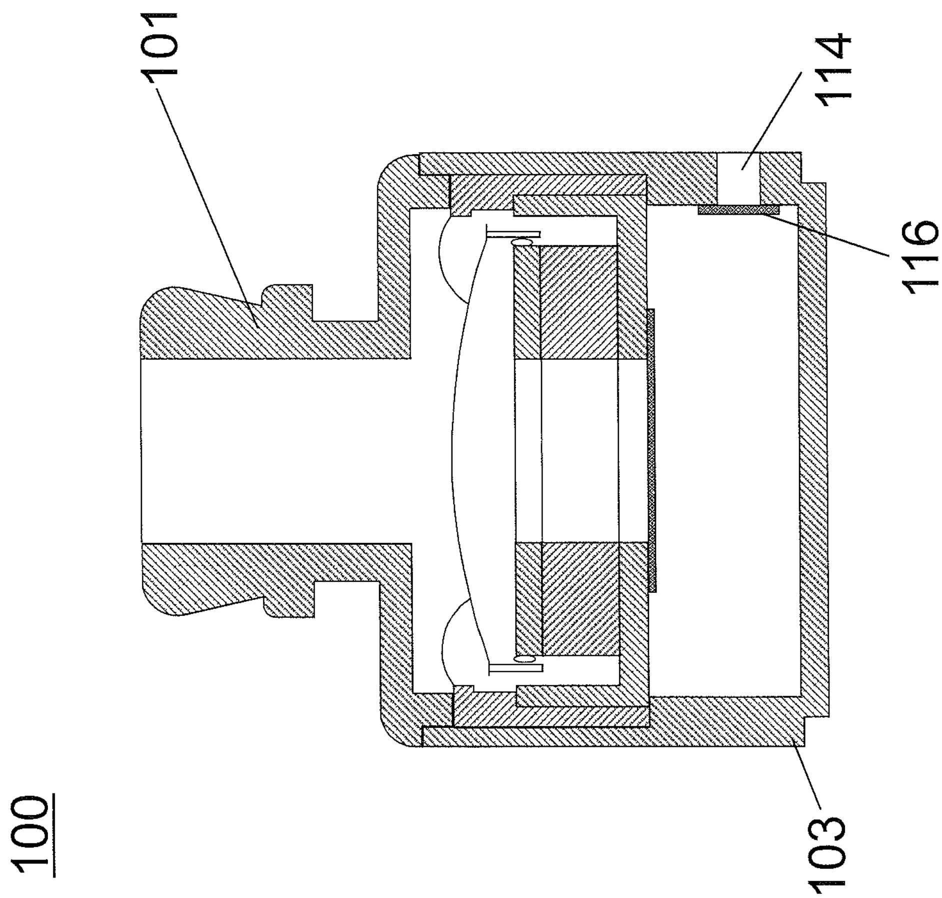
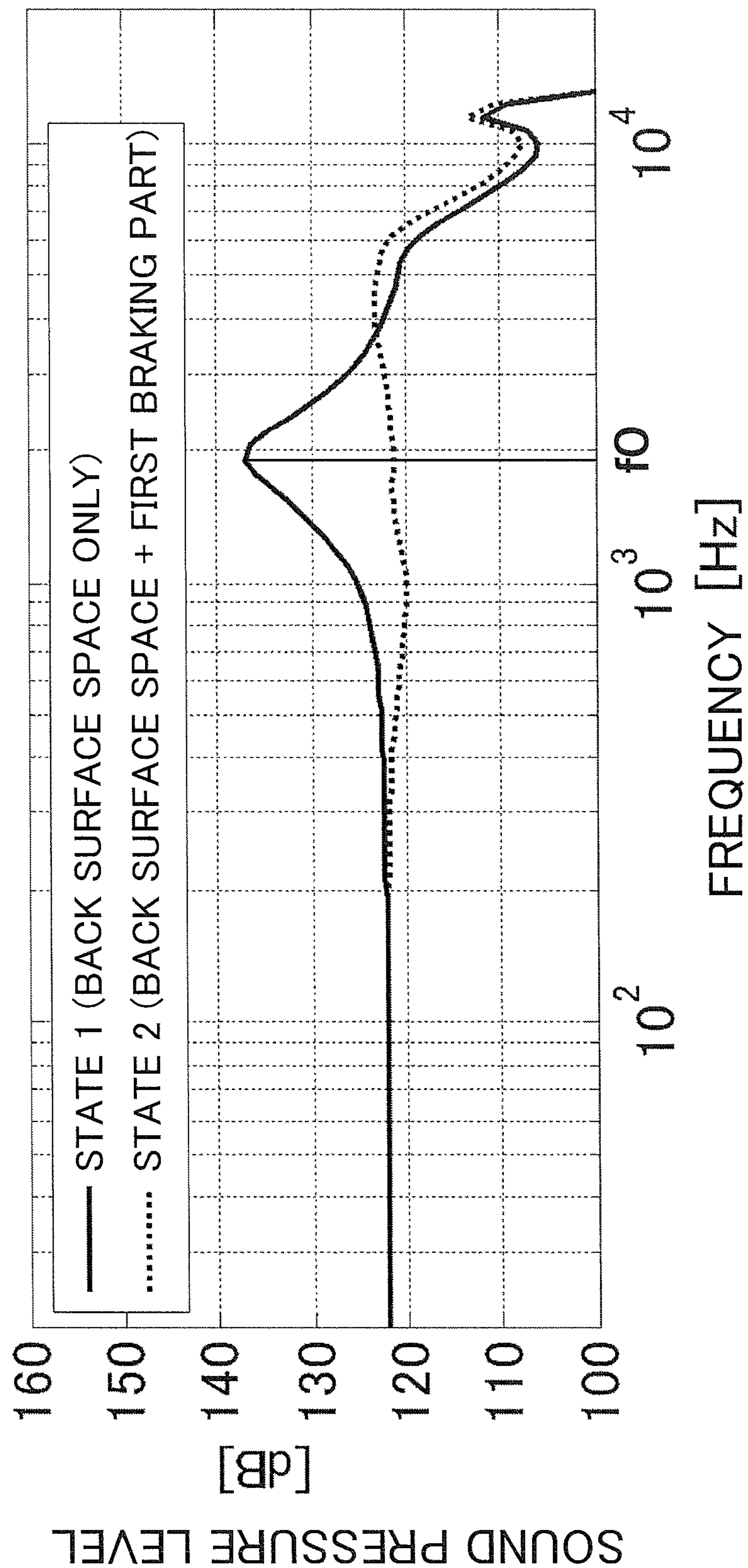



FIG. 3

FIG. 4


STATE 1 (BACK SURFACE SPACE ONLY)
STATE 2 (BACK SURFACE SPACE + FIRST BRAKING PART)
160
150
140
130
120
110
100
SOUND PRESSURE LEVEL [dB]
$10^2$
$10^3$
$10^4$
f0
FREQUENCY [Hz]

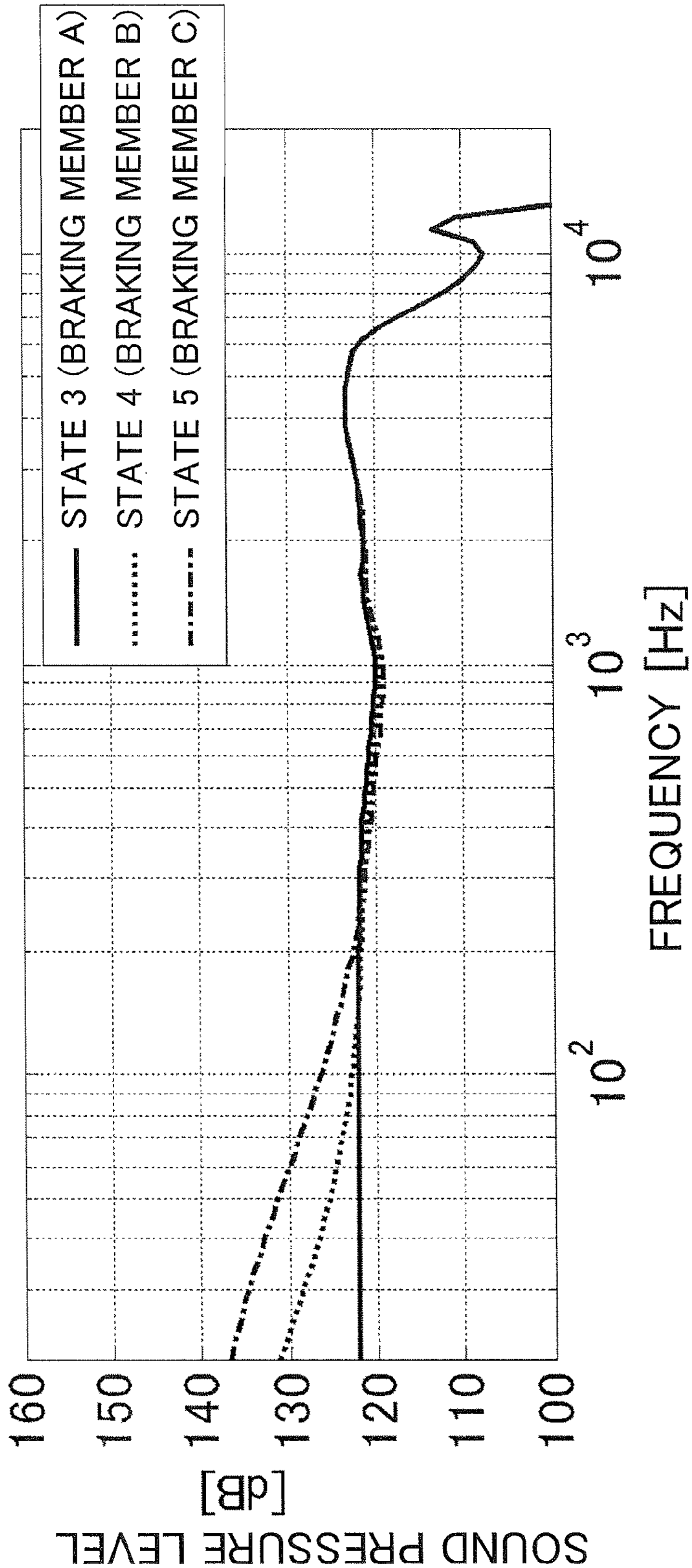
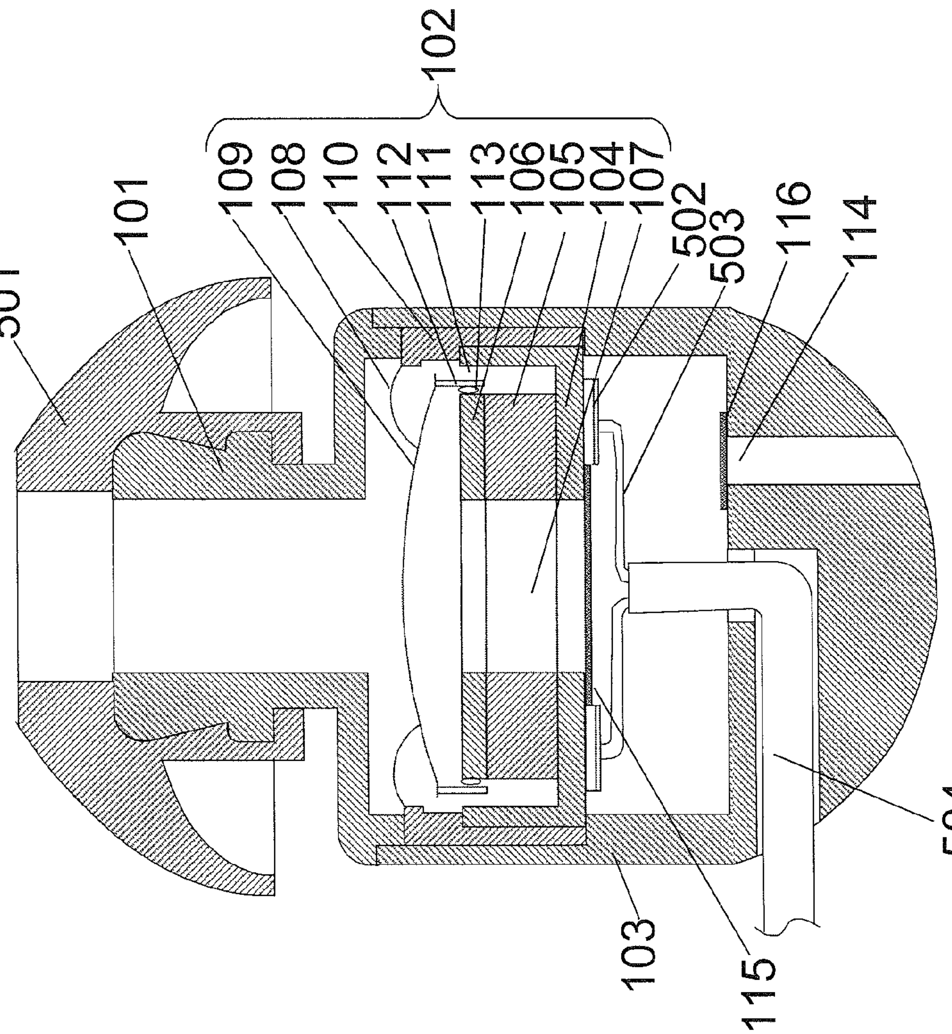

STATE 3 (BRAKING MEMBER A)
STATE 4 (BRAKING MEMBER B)
STATE 5 (BRAKING MEMBER C)
SOUND PRESSURE LEVEL [dB]
160
150
140
130
120
110
100
$10^2$
$10^3$
$10^4$
FREQUENCY [Hz]

FIG.5

FIG. 6

500


501
101
109
108
110
112
111
113
106
105
104
107
102
502
503
116
114
504
103
115

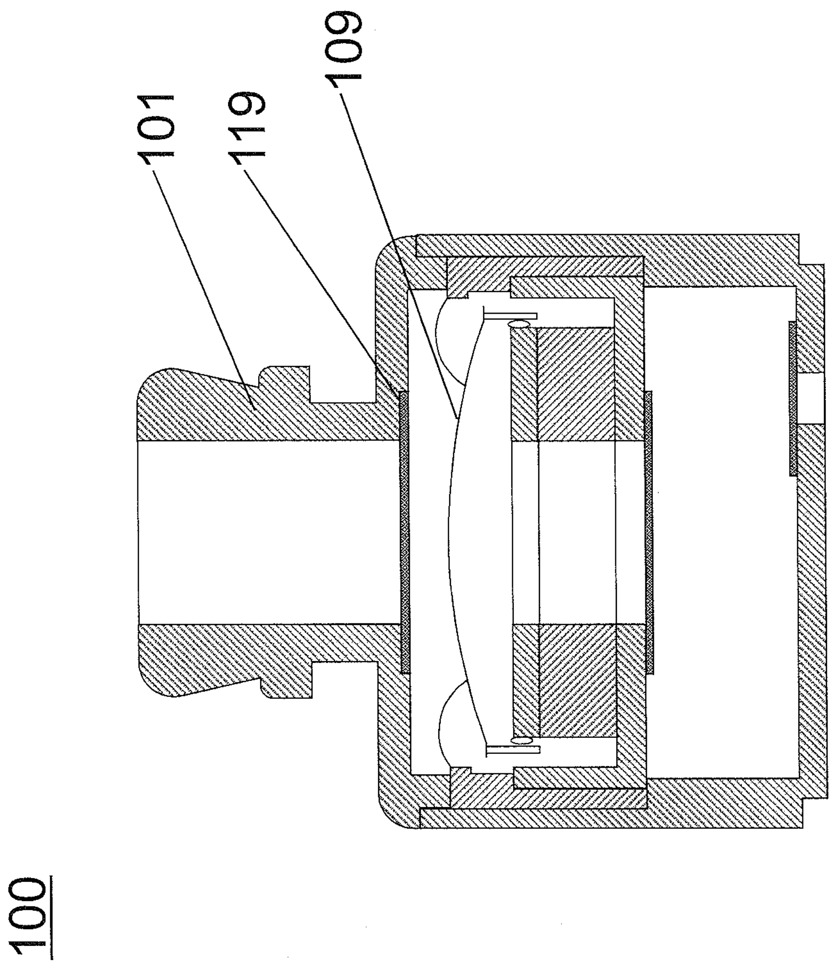



FIG. 7

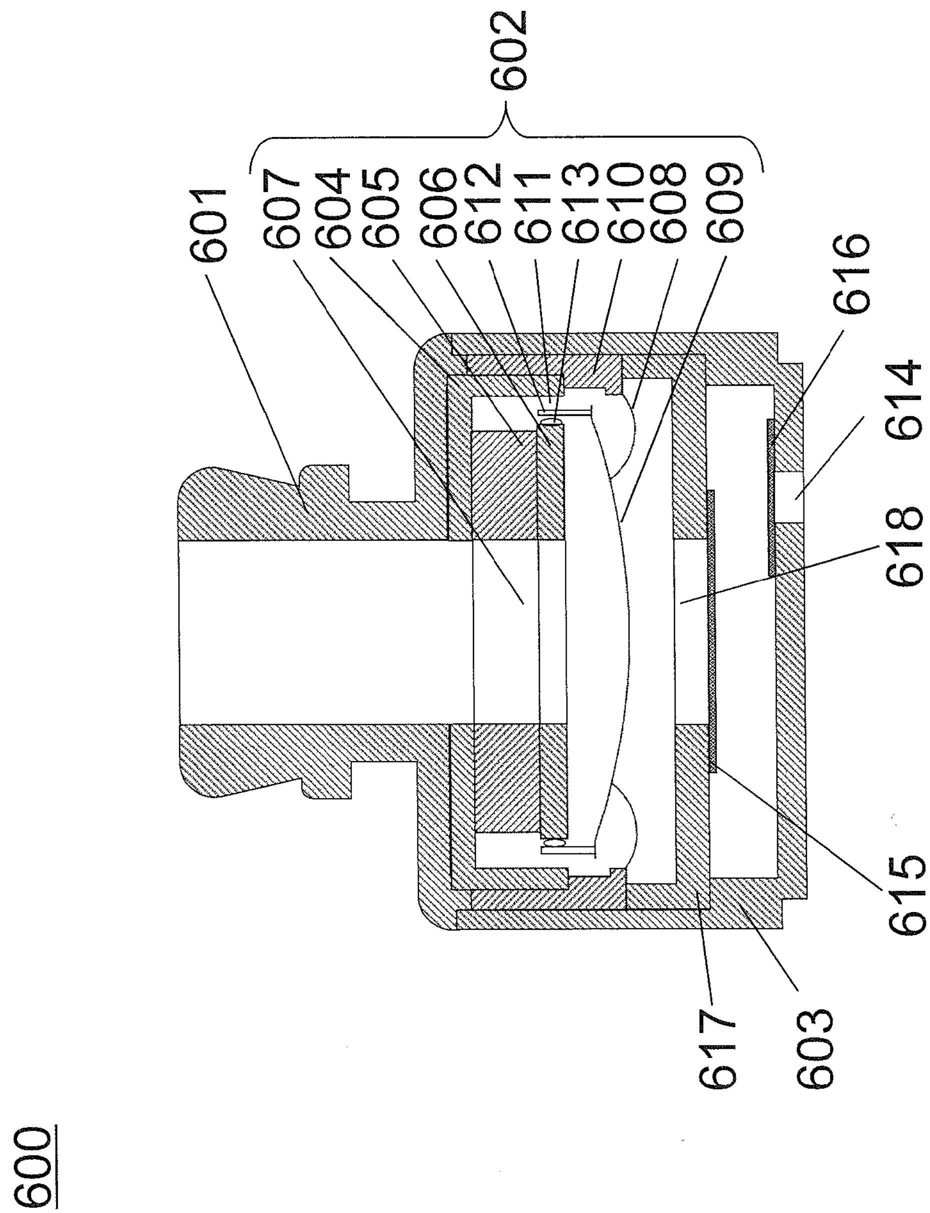

600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618

FIG. 8

FIG. 9

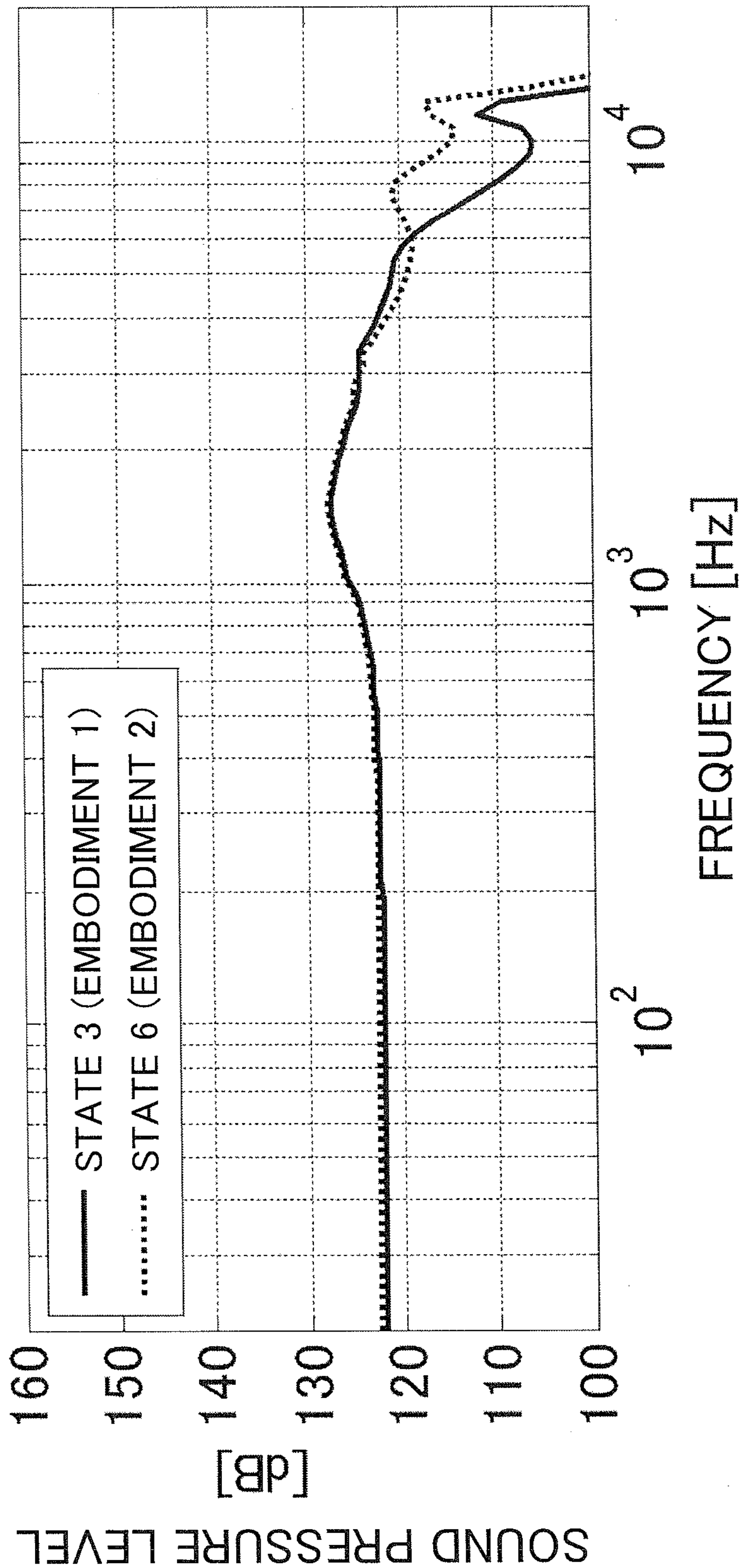

STATE 3 (EMBODIMENT 1)
STATE 6 (EMBODIMENT 2)
160
150
140
130
120
110
100
SOUND PRESSURE LEVEL
[dB]
$10^2$
$10^3$
$10^4$
FREQUENCY [Hz]

FIG. 11

800

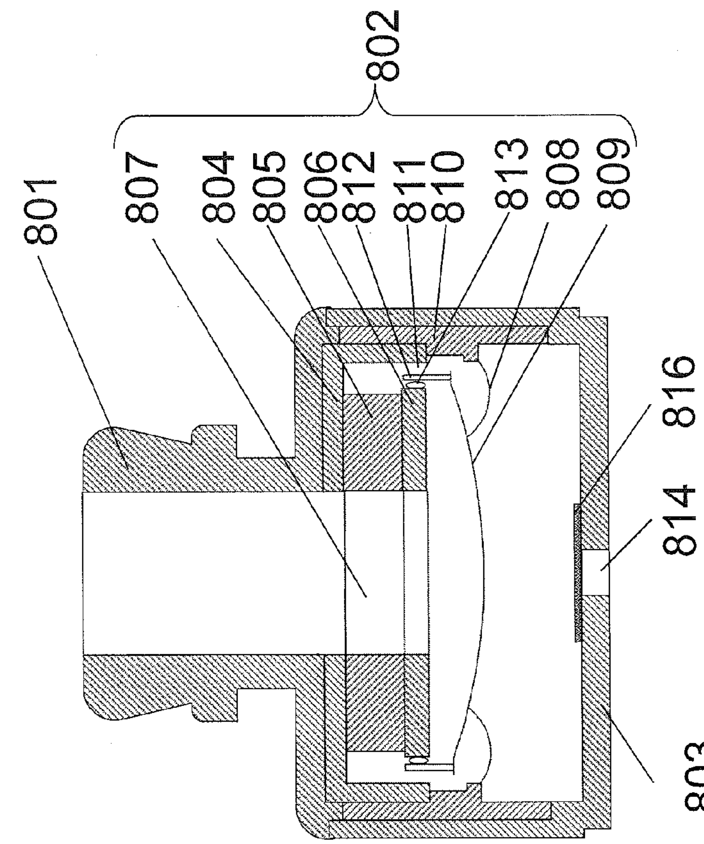



FIG. 10

600

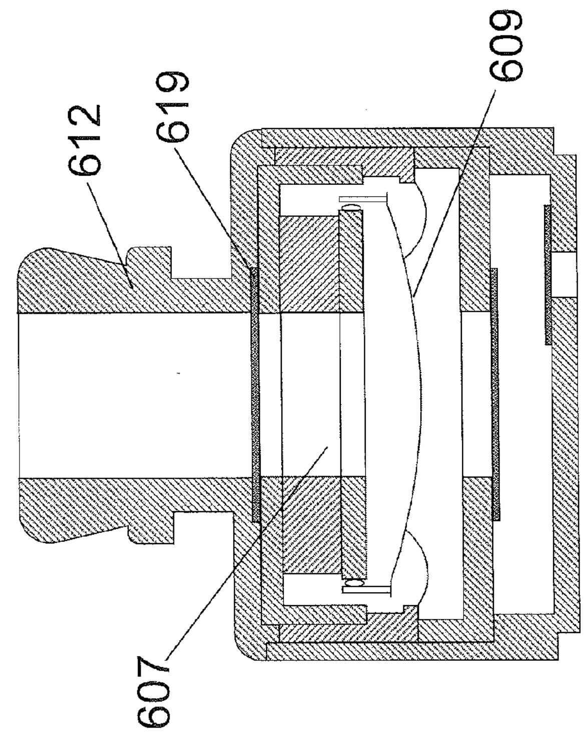


FIG. 12

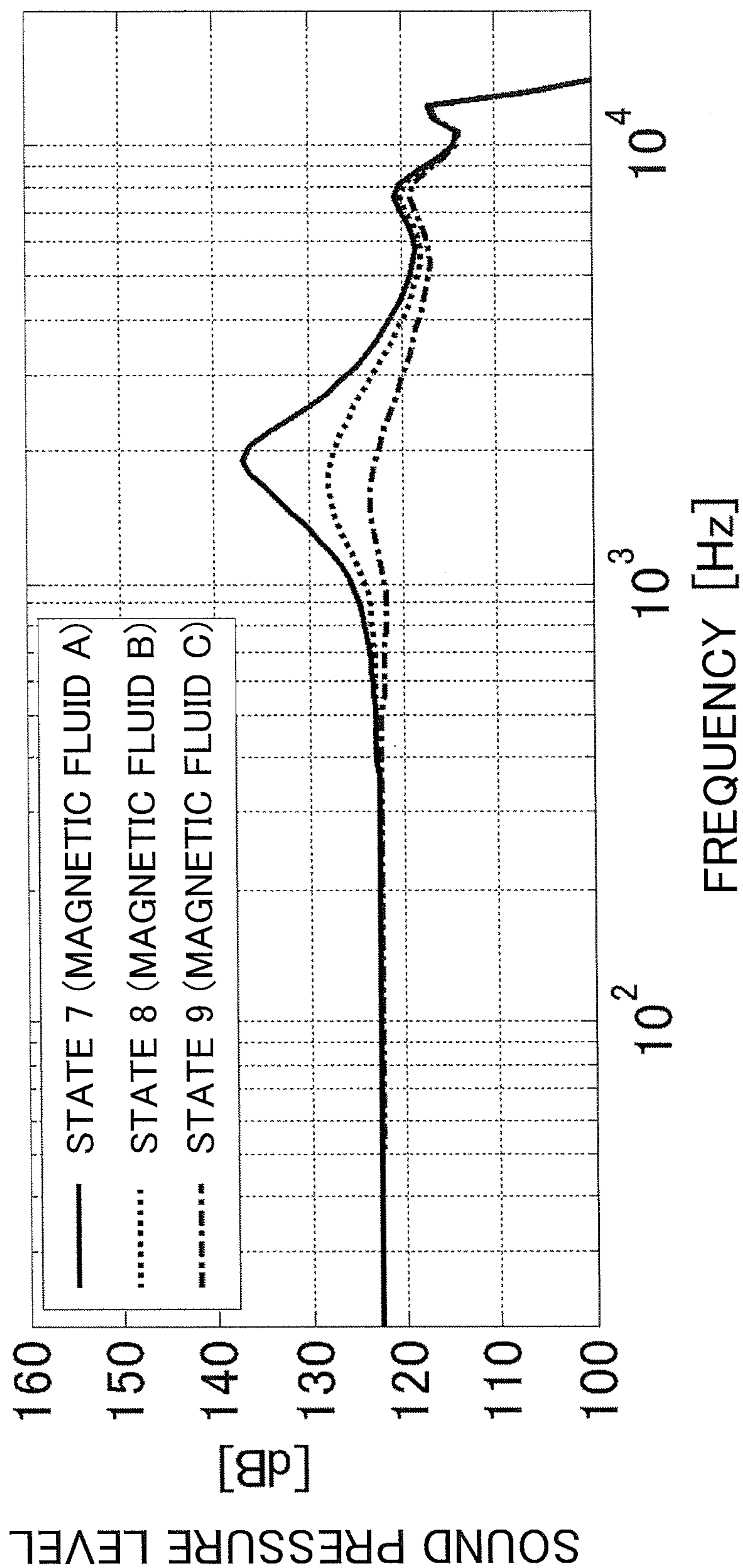

SOUND PRESSURE LEVEL [dB]
160
150
140
130
120
110
100
FREQUENCY [Hz]
$10^2$
$10^3$
$10^4$
STATE 7 (MAGNETIC FLUID A)
STATE 8 (MAGNETIC FLUID B)
STATE 9 (MAGNETIC FLUID C)

FIG. 13

800

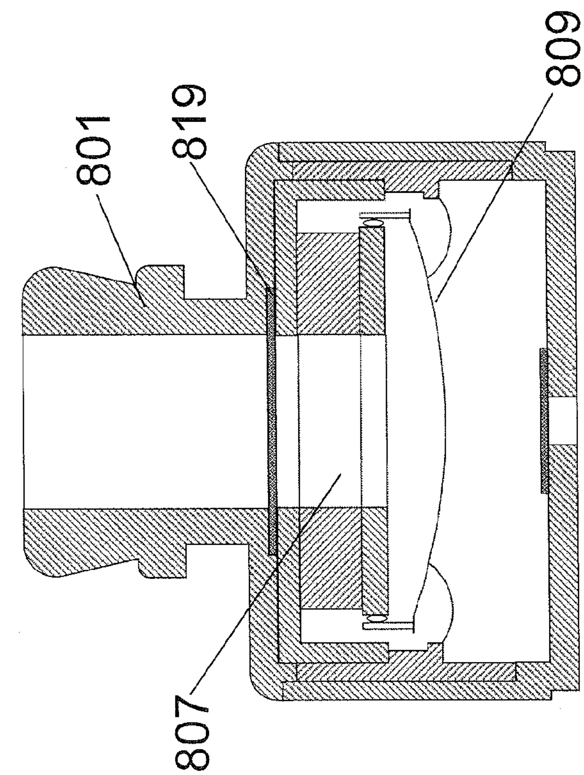



FIG. 14

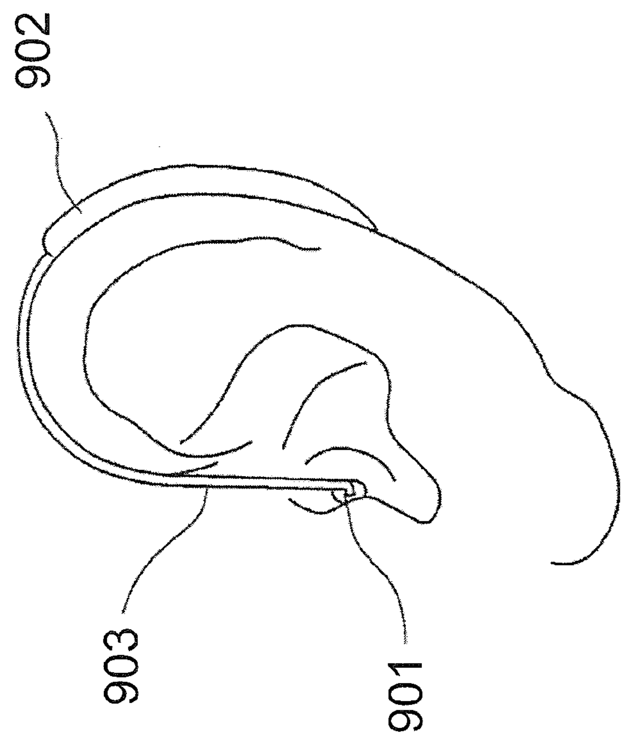


FIG. 15

PRIOR ART

1000

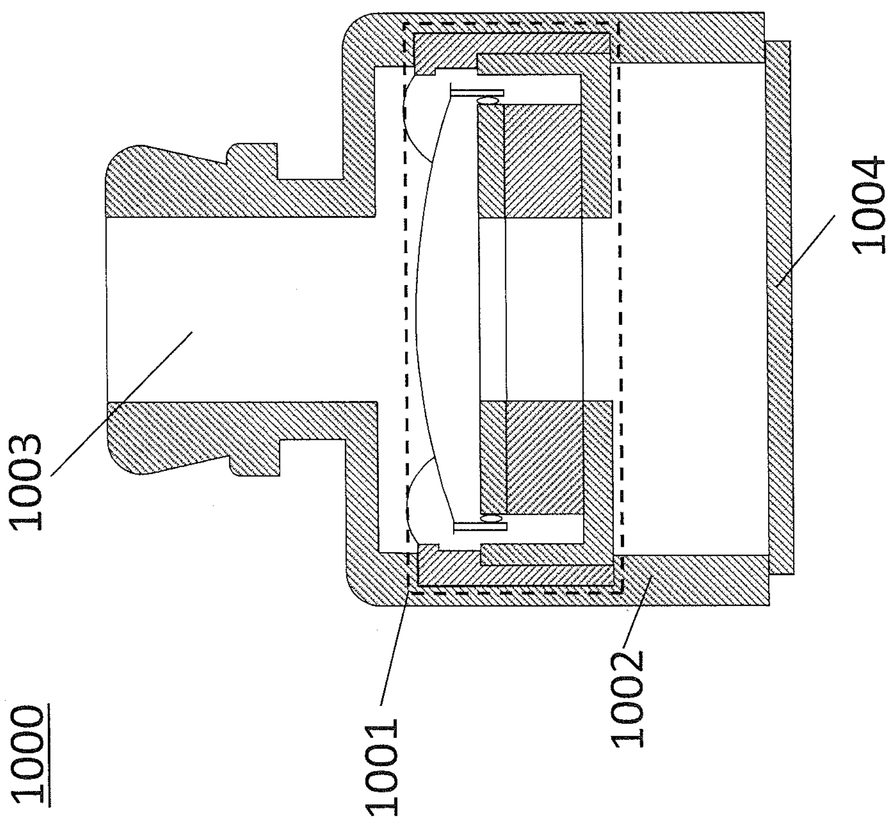
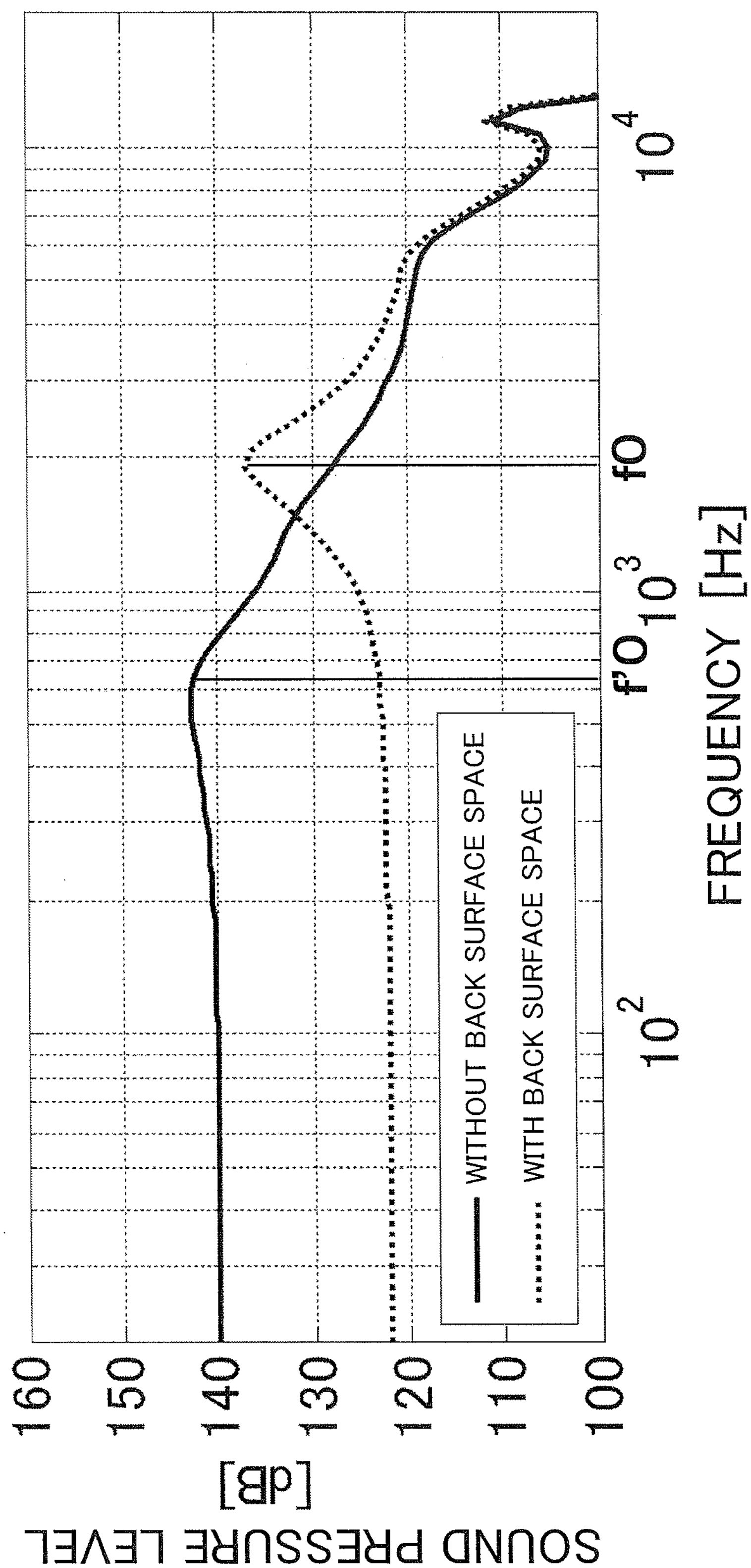


FIG. 16

PRIOR ART



# EARPHONE

## TECHNICAL FIELD

The present disclosure relates to earphones. More particularly, the present disclosure relates to earphones capable of adjusting sound pressure frequency characteristics.

## BACKGROUND ART

In recent years, a small-size loudspeaker unit has been proposed, in which the minimum resonance frequency of the loudspeaker unit is reduced to several hundreds of Hz by using a magnetic fluid. In televisions and mobile phones, use of such a loudspeaker unit can increase the low frequency band characteristics, as compared to conventional loudspeaker units. However, when the loudspeaker unit having the reduced minimum resonance frequency is used in equipment such as earphones in which the loudspeaker unit is driven in a closed space surrounded by an eardrum and an external auditory canal, the low frequency band characteristics become excessive as compared to the high frequency band characteristics, and therefore, the sound pressure frequency characteristics need to be adjusted in some way.

As a method for adjusting the sound pressure frequency characteristics of the conventional earphones, a method has been proposed, in which a space is provided at a back surface of the loudspeaker unit. As a prior art literature relating to the present disclosure, for example, Patent Literature 1 has been known, which discloses a configuration of an earphone in which a space is provided on a back surface of a loudspeaker unit in a housing in which the loudspeaker unit is installed, and the volume of the space provided at the back surface of the loudspeaker unit is adjusted to adjust the sound pressure frequency characteristics.

## CITATION LIST

### Patent Literature

[PTL 1] Japanese Laid-Open Patent Publication No. 2008-283398

## SUMMARY OF THE INVENTION

### Problems to be Solved by the Invention

In the configuration of the conventional earphone, by providing the space at the back surface of the loudspeaker unit, the minimum resonance frequency of the loudspeaker unit can be increased. Thereby, in the loudspeaker unit having the low minimum resonance frequency, a difference in sound pressure levels between a frequency range lower than the minimum resonance frequency and a frequency range higher than the minimum resonance frequency is improved. However, with increase in the minimum resonance frequency, a Q value in the minimum resonance frequency increases, and an undesirable peak is generated. Further, in the configuration of the conventional earphone, in the frequency range lower than the minimum resonance frequency, the sound pressure level becomes constant, and therefore, the sound pressure frequency characteristics in the low frequency range cannot be freely adjusted.

The present disclosure takes into consideration the above problems, and has an object to provide an earphone capable of suppressing a peak that occurs when the minimum resonance



frequency increases, and freely adjusting the sound pressure frequency characteristics in the low frequency range.

### Solution to the Problems

To achieve the above object, an earphone according to an aspect of the present disclosure includes: a loudspeaker unit; a sound conductive tube which is connected to a front surface having a diaphragm included in the loudspeaker unit, and has a hole through which a sound generated from the loudspeaker unit is emitted; a housing which is connected to a back surface of the loudspeaker unit so that a space is formed between the housing and the back surface of the loudspeaker unit, and has a first air hole connecting the space to external air; a first braking part which closes a sound hole of the loudspeaker unit; and a second braking part which closes the first air hole.

### Advantageous Effects of the Invention

According to the present disclosure, an earphone having a space provided at a back surface of a loudspeaker unit can realize the sound pressure frequency characteristics suitable for the earphone by using two braking parts.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a schematic cross-sectional diagram showing the configuration of an earphone according to Embodiment 1 of the present disclosure.

FIG. **1**B is a schematic cross-sectional diagram taken along a line A-A' in FIG. **1**A.

FIG. **2** is a schematic cross-sectional diagram showing the configuration of another example of the earphone according to Embodiment 1 of the present disclosure.

FIG. **3** is a schematic cross-sectional diagram showing the configuration of another example of the earphone according to Embodiment 1 of the present disclosure.

FIG. **4** is a diagram showing sound pressure frequency characteristics relating to a first braking part according to Embodiment 1 of the present disclosure.

FIG. **5** is a diagram showing sound pressure frequency characteristics relating to a second braking part according to Embodiment 1 of the present disclosure.

FIG. **6** is a schematic cross-sectional diagram showing the configuration of the earphone being used, according to Embodiment 1 of the present disclosure.

FIG. **7** is a schematic cross-sectional diagram showing the configuration of another example of the earphone according to Embodiment 1 of the present disclosure.

FIG. **8** is a schematic cross-sectional diagram showing the configuration of an earphone according to Embodiment 2 of the present disclosure.

FIG. **9** is a diagram showing sound pressure frequency characteristics of the earphone according to Embodiment 2 of the present disclosure.

FIG. **10** is a schematic cross-sectional diagram showing the configuration of another example of the earphone according to Embodiment 2 of the present disclosure.

FIG. **11** is a schematic cross-sectional diagram showing the configuration of an earphone according to Embodiment 3 of the present disclosure.

FIG. **12** is a diagram showing sound pressure frequency characteristics of the earphone according to Embodiment 3 of the present disclosure.

FIG. **13** is a schematic cross-sectional diagram showing the configuration of another example of the earphone according to Embodiment 3 of the present disclosure.

FIG. **14** is a diagram showing an example of an external view of a hearing aid according to Installation Example of the present disclosure.

FIG. **15** is a schematic cross-sectional diagram showing the configuration of the conventional earphone.

FIG. **16** is a diagram showing the sound pressure frequency characteristics depending on presence/absence of a back surface space in the conventional earphone.

## DESCRIPTION OF EMBODIMENTS

In order to describe the problems to be solved by the present disclosure, the conventional earphone disclosed in Patent Literature 1 will be described with reference to the drawings. FIG. **15** is a schematic cross-sectional diagram showing the configuration of the conventional earphone **1000**. The conventional earphone **1000** includes a loudspeaker unit **1001**, a housing **1002**, a sound output hole **1003** provided through the housing **1002**, and a back surface panel **1004** fitted to the housing **1002**. A user replaces the back surface panel **1004** of the earphone **1000** to adjust the volume of the back surface space formed by the loudspeaker unit **1001**, the housing **1002**, and the back surface panel **1004**, and thus the user can select a desired minimum resonance frequency.

FIG. **16** is a diagram showing the sound pressure frequency characteristics depending on presence/absence of the back surface space in the conventional earphone **1000**. In FIG. **16**, a horizontal axis represents the frequency, and a vertical axis represents the sound pressure level. The sound pressure frequency characteristics in the state where no back surface space is provided (that is, in the configuration where the earphone **1000** has no back surface panel **1004**) are represented by a solid line, while the sound pressure frequency characteristics in the state where a back surface space is provided (that is, in the configuration where the earphone **1000** has the back surface panel **1004**) is represented by a dotted line. It can be confirmed from FIG. **16** that the back surface space provided in the earphone **1000** causes the minimum resonance frequency to increase from f'0 to f0, and enables adjustment of a difference between the sound pressure level in the frequency range lower than the minimum resonance frequency f0 and the sound pressure level in the frequency range higher than the minimum resonance frequency f0.

However, the above-mentioned conventional earphone **1000** has the following drawbacks. In the conventional earphone **1000**, an undesirable peak is generated in the minimum resonance frequency f0. Further, in the conventional earphone **1000**, in the frequency range lower than the minimum resonance frequency f0, the sound pressure level becomes constant, and therefore, the sound pressure frequency characteristics in the frequency range lower than the minimum resonance frequency f0 cannot be freely adjusted.

As a method of adjusting the sound pressure frequency characteristics, a method has been known, in which an air hole is formed through the back surface panel **1004** to adjust the airtightness inside the housing **1002**. However, even in the method of providing the air hole through the back surface panel **1004**, a peak that occurs when the minimum resonance frequency increases cannot be sufficiently suppressed, and the sound pressure frequency characteristics in the frequency range lower than the minimum resonance frequency f0 cannot be freely adjusted.

Therefore, the inventors of the present disclosure has devised an earphone capable of suppressing a peak that occurs when the minimum resonance frequency increases, and freely adjusting the sound pressure frequency characteristics in the frequency range lower than the minimum resonance frequency.

Various aspects of the present disclosure based on the newly devised earphone are as follows.

An earphone according to an aspect of the present disclosure includes: a loudspeaker unit; a sound conductive tube which is connected to a front surface having a diaphragm included in the loudspeaker unit, and has a hole through which a sound generated from the loudspeaker unit is emitted; a housing which is connected to a back surface of the loudspeaker unit so that a space is formed between the housing and the back surface of the loudspeaker unit, and has a first air hole connecting the space to external air; a first braking part which closes a sound hole of the loudspeaker unit; and a second braking part which closes the first air hole.

According to this aspect, a peak that occurs due to increase in the minimum resonance frequency can be suppressed by the first braking part, and furthermore, a sound quality suitable for the earphone can be realized by the degree of the braking effect of the second braking part.

In another aspect, for example, the first braking part and the second braking part are made of a nonwoven fabric or a woven fabric.

Further, in another aspect, for example, a third braking part that closes the hole of the sound conductive tube is further provided on the loudspeaker unit side of the sound conductive tube.

According to the another aspect, a resonance can be suppressed, which occurs due to the space formed between the diaphragm and the sound conductive tube and the mass of the air inside the sound conductive tube.

An earphone according to another aspect includes: a loudspeaker unit; a sound conductive tube which is connected to a surface opposite to a front surface having a diaphragm included in the loudspeaker unit, and has a hole through which a sound generated from the loudspeaker unit is emitted; a housing which is connected to a front surface of the loudspeaker unit so that a space is formed between the housing and the front surface of the loudspeaker unit, and has a first air hole connecting the space to external air; a back surface plate connected to the front surface of the loudspeaker unit, and has a second air hole; a first braking part which closes the second air hole; and a second braking part which closes the first air hole.

According to the another aspect, a peak that occurs due to increase in the minimum resonance frequency can be suppressed by the first braking part, and furthermore, a sound quality suitable for the earphone can be realized by the degree of the braking effect of the second braking part. Moreover, the high frequency characteristics can be improved by reducing the volume of the space formed between the diaphragm and the sound conductive tube.

Further, in another aspect, for example, the first braking part and the second braking part are made of a nonwoven fabric or a woven fabric.

Further, in another aspect, for example, a third braking part that closes the hole of the sound conductive tube is further provided on the loudspeaker unit side of the sound conductive tube.

According to the another aspect, a resonance can be suppressed, which occurs due to the space formed between the diaphragm and the sound conductive tube and the mass of the air inside the sound conductive tube.

Furthermore, in another aspect of the present disclosure, the above-mentioned earphone may be provided in a hearing aid.

Hereinafter, embodiments will be described in detail with reference to the drawings as appropriate. However, there will be instances in which detailed description beyond what is necessary is omitted. For example, detailed description of subject matter that is previously well-known, as well as redundant description of components that are substantially the same will in some cases be omitted. This is to prevent the following description from being unnecessarily lengthy, in order to facilitate understanding by a person of ordinary skill in the art. The applicant provides the following description and the accompanying drawings in order to allow a person of ordinary skill in the art to sufficiently understand the present disclosure, and the description and the drawings are not intended to restrict the subject matter of the scope of the patent claims.

Embodiment 1

Hereinafter, Embodiment 1 will be described. Firstly, the configuration of an earphone **100** according to the present embodiment will be described. FIG. **1**A is a schematic cross-sectional view of the earphone **100** according to the present embodiment. FIG. **1**B is a schematic cross-sectional view taken along a line A-A' in FIG. **1**A and viewed in the direction of an arrow B. The earphone **100** includes a sound conductive tube **101**, a loudspeaker unit **102**, a housing **103**, a first braking part **115**, and a second braking part **116** joined to the housing **103**. The loudspeaker unit **102** includes a yoke **104**, a magnet **105**, a plate **106**, a sound hole **107**, support members **108** each having an arch-shaped cross section, a diaphragm **109** supported by the support members **108**, a frame **110** to which the support members **108** are joined, a magnetic gap **111** produced by the yoke **104** and the plate **106**, a voice coil **112** held in the magnetic gap **111**, and a magnetic fluid **113** that fills a space between the plate **106** and the voice coil **112** in the magnetic gap **111**. The first braking part **115** is joined to the yoke **104** so as to close the sound hole **107**, and the second braking part **116** is joined to the housing **103** so as to close a first air hole **114** provided through the housing **103**. Further, in the earphone **100**, if the sound conductive tube **101** side is an upper side, a space between a lower surface of the yoke **104** and the housing **103** serves as a back surface space. In addition, the earphone **100** includes a plurality of support members **108** (in FIG. **1**B, four support members **108**), and the plurality of support members **108** partially support the diaphragm **109** in a vibratable manner.

The first braking part **115** and the second braking part **116** may be made of any material, such as a braking fabric or a plurality of through-holes, so long as the braking effect can be added. For example, the first braking part **115** and the second braking part **116** are made of a material such as a mesh-type nonwoven fabric or woven fabric. Alternatively, for example, the first braking part **115** and the second braking part **116** may be made of a porous material that fills the sound hole **107** and the first air hole **114**, respectively. Further, while in the present embodiment the first braking part **115** is joined to the yoke **104**, the first braking part **115** may be joined to the plate **106** as shown in FIG. **2**. Further, while in the present embodiment the second braking part **116** is joined to the inside of the earphone **100** in the housing **103**, the second braking part **116** may be joined to the outside of the earphone **100** as shown in FIG. **2**.

In the present embodiment, if the sound conductive tube **101** side is an upper side of the earphone **100**, the first air hole **114** is provided on a bottom wall of the housing **103**. However, the first air hole **114** may be provided on a side wall of the housing **103** as shown in FIG. **3**. The position where the first air hole **114** is provided is not particularly limited, and the first air hole **114** may be provided at any position so long as it is not covered with an ear when the earphone **100** is inserted in the ear.

Next, the operation of the earphone **100** configured as described above, when it is inserted in an external auditory canal, will be described. When an electric signal is input to the voice coil **112**, the voice coil **112** vibrates in accordance with the Fleming's left hand rule. Since the voice coil **112** is joined to the diaphragm **109**, the diaphragm **109** vibrates in the same direction as the vibration of the voice coil **112**. As a result, a sound wave is generated from the diaphragm **109**. At this time, since the support members **108** do not enclose the entire circumference of the diaphragm **109** but are partially joined to the diaphragm **109**, the compliance of the support members **108** is sufficiently high as compared to the conventional support member that encloses the entire circumference of the diaphragm **109**, and thereby the minimum resonance frequency is reduced to several hundreds of Hz. However, since the loudspeaker unit **102** is joined to the housing **103**, the compliance of the earphone **100** increases, and thereby the minimum resonance frequency increases. Simultaneously with this, a peak is generated in the minimum resonance frequency. However, this peak is reduced by the acoustic braking of the first braking part **115**. Further, the sound pressure frequency characteristics in a frequency range lower than the minimum resonance frequency is determined by the acoustic braking of the second braking part **116**. The above operation will be described in detail below.

FIG. **4** is a diagram showing the sound pressure frequency characteristics relating to the first braking part **115** of the earphone **100** according to the present embodiment. In FIG. **4**, a horizontal axis represents the frequency, and a vertical axis represents the sound pressure level. The sound pressure frequency characteristics in state **1**, wherein the sound conductive tube **101** side is a front side of the earphone **100**, and only a space is provided on the back surface of the loudspeaker unit **102**, is represented by a solid line. The sound pressure frequency characteristics in state **2**, wherein a space and the first braking part **115** are provided on the back surface of the loudspeaker unit **102**, is represented by a dotted line. As shown in FIG. **4**, in the state **1** where only the space is provided on the back surface of the loudspeaker unit **102**, a peak is generated in the minimum resonance frequency f0. However, by providing the first braking part **115** as in the state **2**, the passing amount of sound of the minimum resonance frequency f0 can be adjusted, and thereby the peak in the minimum resonance frequency f0 can be suppressed.

Next, FIG. **5** is a diagram showing the sound pressure frequency characteristics relating to the second braking part **116** of the earphone **100** according to the present embodiment. In FIG. **5**, a horizontal axis represents the frequency, and a vertical axis represents the sound pressure level. In FIG. **5**, states **3**, **4**, and **5** represent the states where braking members A, B, and C are used as the second braking part **116** of the earphone **100**, respectively. The braking members A, B, and C have the braking effects in descending order. The braking member A provides the substantially hermetically closed state where no sound passes through the first air hole **114**, and the braking members B and C provide the states where sound is more difficult to pass through the first air hole **114** in this order. Further, in FIG. **5**, the state **3** is represented by a solid line, the state **4** is represented by a dotted line, and the state **5** is represented by a dashed-dotted line. As shown in FIG. **5**, by adjusting the magnitude of the braking effect of the second braking part **116**, the amount of sound passing through the second braking part **116**, which sound has frequencies lower than the minimum resonance frequency M, can be adjusted, and thereby the sound pressure frequency characteristics in the low frequency range can be adjusted.

As described above, in the present embodiment, also when the loudspeaker unit **102** having the low minimum resonance frequency is applied to the earphone **100**, it is possible to realize the sound pressure frequency characteristics suitable for the earphone **100** by providing the back surface space, the first braking part **115**, and the second braking part **116**.

Further, when a braking fabric such as a mesh-type non-woven fabric or woven fabric is used as a material of the first braking part **115** and the second braking part **116**, if the magnetic fluid **113** is scattered due to dropping impact or the like of the earphone **100**, the braking fabric absorbs the magnetic fluid **113** to prevent the magnetic fluid **113** from flowing outside the earphone **100**.

Next, an example of a case where the earphone **100** according to the present disclosure is actually used. FIG. **6** is a schematic cross-sectional diagram showing the configuration of the earphone **500** corresponding to the earphone **100** of the present embodiment which is actually used. The earphone **500** includes an ear chip **501**, a terminal **502**, wires **503**, and a cord **504** having the wires **503** therein. A hole through which the cord **504** passes, which is formed through the housing **103**, is hermetically closed by a rubber plug or the like (not shown). The internal configuration of the earphone **500** is identical to that of the above-mentioned earphone **100**.

The operation of the earphone **500** configured as mentioned above, when it is fixed in an external auditory canal of a user via the ear chip **501**, will be described. Since the voice coil **112** and the wires **503** are connected to the terminal **502**, an electric signal outputted from equipment connected to the wires **503** is transmitted to the voice coil **112**, and the voice coil **112** vibrates in accordance with the Fleming's left hand rule. Since the voice coil **112** is joined to the diaphragm **109**, the diaphragm **109** vibrates in the same direction as the vibration of the voice coil **112**. As a result, a sound wave is generated from the diaphragm **109**. The generated sound wave reaches an eardrum of the user via the sound conductive tube **101**, the ear chip **501**, and the external auditory canal, and thereby the user perceives the sound wave. In the present embodiment, by providing the back surface space, the first braking part **115**, and the second braking part **116**, even the loudspeaker unit **102** having the low minimum resonance frequency can realize the sound pressure frequency characteristics suitable for the earphone **500**, and therefore, the user of the earphone **500** is provided with high sound quality.

While in the present embodiment the support members **108** supporting the diaphragm **109** are partially joined to the diaphragm **109**, a support member **108** may be joined to the entire circumference of the diaphragm **109**. The magnetic fluid **113** is provided to prevent a sound wave having a phase opposite to the phase of the sound wave generated from the diaphragm **109** toward the sound conductive tube **101**, from traveling from a surface of the diaphragm **109** on the side opposite to the sound conductive tube **101** toward the sound conductive tube **101**. If a support member **108** is joined to the entire circumference of the diaphragm **109**, the support member **108** and the diaphragm **109** prevent a sound wave having a phase opposite to the phase of the sound wave generated from the diaphragm **109** toward the sound conductive tube **101**, from traveling from a surface of the diaphragm **109** on the side opposite to the sound conductive tube **101** toward the sound conductive tube **101**. Therefore, the magnetic fluid **113** is not an indispensable component in the present disclosure. That is, the magnetic fluid **113** may be removed from the components of the earphone **100**, and the support member **108** may be joined to the entire circumference of the diaphragm **109**.

Further, as shown in FIG. **7**, in the present embodiment, a third braking part **119** joined to the sound conductive tube **101** may be provided in order to suppress a resonance that occurs due to the space formed between the diaphragm **109** and the sound conductive tube **101** and the mass of the air inside the sound conductive tube **101**.

## Embodiment 2

Hereinafter, an earphone **600** according to Embodiment 2 will be described. The earphone **600** is characterized by that, in the earphone **100** of the Embodiment 1, if the sound conductive tube **101** side is an upper side, the loudspeaker unit **102** is inverted so that the diaphragm **109** faces the bottom wall of the housing **103**, and a back surface plate through which a second air hole is formed is provided inside the housing, and the first braking part is joined to the back surface plate so as to close the second air hole. FIG. **8** is a schematic cross-sectional view of the earphone **600** according to the present embodiment. The earphone **600** includes a sound conductive tube **601**, a loudspeaker unit **602**, a housing **603**, a back surface plate **617**, a first braking part **615** joined to the back surface plate **617** so as to close a second air hole **618** provided through the back surface plate **617**, and a second braking part **616** joined to the housing **603** so as to close a first air hole **614** provided through the housing **603**. The loudspeaker unit **602** includes a yoke **604**, a magnet **605**, a plate **606**, a sound hole **607**, support members **608** each having an arch-shaped cross section, a diaphragm **609** supported by the support members **608**, a frame **610** joined to the support members **608**, a magnetic gap **611** produced by the yoke **604** and the plate **606**, a voice coil **612** held in the magnetic gap **611**, and a magnetic fluid **613** that fills a space between the plate **606** and the voice coil **612** in the magnetic gap **611**. In addition, the back surface plate **617** is joined to the frame **610**.

Next, the operation of the earphone **600** thus configured when it is inserted in an external auditory canal of a user will be described. Like in Embodiment 1, when an electric signal is input to the voice coil **612**, the voice coil **612** vibrates, and a sound wave is generated from the diaphragm **609**. Embodiment 2 is greatly different from Embodiment 1 in that the sound wave having passed through the sound hole **607** travels toward the external auditory canal of the user via the sound conductive tube **601**. The earphone **600** thus configured realizes reduction in the volume of the space formed between the diaphragm **609** and the sound conductive tube **601**, as compared to Embodiment 1. That is, in the earphone **600**, the volume of a space formed between the diaphragm **609** and the sound conductive tube **601** is reduced to the volume of a space formed between the diaphragm **609** and the sound hole **607**. Since the space formed between the diaphragm **609** and the sound conductive tube **601** serves to reduce the high frequency characteristics, the high frequency characteristics can be improved in the present embodiment as compared to Embodiment 1. However, when the configuration of the present embodiment is realized, if the sound conductive tube **601** side is a front side of the earphone **600**, the first braking part **615** cannot be provided in the back surface space of the loudspeaker unit **602**. Therefore, the back surface plate **617** is provided inside the housing **603** and on the back surface side of the loudspeaker unit **602**, and the first braking part **615** is joined so as to close the second air hole **618** formed through the back surface plate **617**.

FIG. **9** is a diagram showing the sound pressure frequency characteristics of the earphone **600** according to the present embodiment. In FIG. **9**, a horizontal axis represents the frequency, and a vertical axis represents the sound pressure level. The sound pressure frequency characteristics of the state **3** shown in Embodiment 1 is represented by a solid line, and the sound pressure frequency characteristics of a state **6** according to the present embodiment is shown by a dotted line. The first braking part **115** of the state **3** and the first braking part **615** of the state **6** are implemented by a braking member having the same braking effect, and the second braking part **116** of the state **3** and the second braking part **616** of the state **6** are implemented by a braking member having the same braking effect. It can be confirmed from FIG. **9** that the high frequency characteristics in the vicinity of $8\times10^3$ Hz to $1\times10^4$ Hz are increased by about 10 dB in the state **6** as compared to the state **3**. Accordingly, it is found that the high frequency characteristics can be improved by reducing the volume of the space formed between the diaphragm **609** and the sound conductive tube **601**.

As shown in FIG. **10**, in the present embodiment, a third braking part **619** joined to the sound conductive tube **601** may be provided in order to suppress a resonance that occurs due to the space formed between the diaphragm **609** and the sound hole **607** and the mass of the air inside the sound conductive tube **601**.

Embodiment 3

Hereinafter, an earphone **800** according to Embodiment 3 will be described. The earphone **800** is characterized by that, in the earphone **600** of the Embodiment 2, the back surface plate **617** having the second air hole **618** and the first braking part **615** are not provided. FIG. **11** is a schematic cross-sectional view of the earphone **800** according to the present embodiment. The earphone **800** includes a sound conductive tube **801**, a loudspeaker unit **802**, a housing **803**, and a second braking part **816** joined to the housing **803** so as to close a first air hole **814** provided through the housing **803**. The loudspeaker unit **802** includes a yoke **804**, a magnet **805**, a plate **806**, a sound hole **807**, support members **808** each having an arch-shaped cross section, a diaphragm **809** supported by the support members **808**, a frame **810** joined to the support members **808**, a magnetic gap **811** formed by the yoke **804** and the plate **806**, a voice coil **812** held inside the magnetic gap **811**, and a magnetic fluid **813** that fills a space between the plate **806** and the voice coil **812** in the magnetic gap **811**.

Next, the operation of the earphone **800** thus configured when it is inserted in an external auditory canal of a user will be described. Like Embodiment 2, an electric signal is input to the voice coil **812**, the voice coil **812** vibrates, and a sound wave is generated from the diaphragm **809**. Embodiment 3 is greatly different from Embodiment 2 in that the first braking part is not provided. In Embodiment 2, in order to improve the high frequency characteristics, the diaphragm **609** protrudes to the side opposite to the sound conductive tube **601** to reduce the volume of the space formed between the diaphragm **609** and the sound conductive tube **601**. In the configuration of Embodiment 2, however, the back surface plate **617** needs to be provided inside the housing **603** in order to provide the first braking part **615**. Accordingly, implementation of Embodiment 2 has a problem that the number of components increases. So, in the present embodiment, instead of providing the first braking part and the back surface plate as means to suppress a peak in the minimum resonance frequency, the viscosity of the magnetic fluid **813** is utilized, and thereby the number of components is reduced.

FIG. **12** is a diagram showing the sound pressure frequency characteristics of the earphone **800**. In FIG. **12**, states **7**, **8**, and **9** show the states where magnetic fluids A, B, and C are used as the magnetic fluid **813** of the earphone **800**, respectively. The magnetic fluids A, B, and C have the viscosities in ascending order. Further, in FIG. **12**, the state **7** is represented by a solid line, the state **8** is represented by a dotted line, and the state **9** is represented by a dashed-dotted line. It is found from FIG. **12** that the peak in the minimum resonance frequency can be suppressed by increasing the viscosity of the magnetic fluid **813**. Accordingly, in the present embodiment, even in the state where the first braking part is omitted, the peak in the minimum resonance frequency can be suppressed as in Embodiment 2 by adjusting the viscosity of the magnetic fluid **813**, and therefore, the number of components can be reduced. While in the present embodiment the magnetic fluid **813** is injected into the area surrounded by the plate **806** and the voice coil **812** in the magnetic gap **811**, the magnetic fluid **813** may be injected into the entirety of the magnetic gap **811** in order to enhance the braking effect. Further, the braking effect can be enhanced by bringing the voice coil **812** and the plate **806** closer to each other.

As shown in FIG. **13**, in the present embodiment, a third braking part **819** joined to the sound conductive tube **801** may be provided in order to suppress a resonance that occurs due to the space formed between the diaphragm **809** and the sound hole **807** and the mass of the air inside the sound conductive tube **801**.

In Embodiments 1 to 3, if the accuracy of a technique of forming submicron holes is improved, submicron holes may be formed through the housing and the back surface plate as the first air hole and the second air hole, respectively. Also in this case, it is possible to achieve the same braking effect as that achieved by the configuration including the first braking part and the second braking part.

(Installation Example)

FIG. **14** is a diagram showing an external view of a hearing aid in which any of the earphones according to Embodiments 1 to 3 is installed. With reference to FIG. **14**, a hearing aid according to the present installation example will be described. The hearing aid shown in FIG. **14** includes a receiver part **901**, a hearing aid body **902**, and a lead tube **903**. The configuration of the receiver part **901** is based on the configuration of the earphone according to any of Embodiments 1 to 3.

According to the hearing aid of the present installation example, since the receiver part **901** has the configuration of the earphone of the present disclosure, it is possible to provide a small-size hearing aid which causes a user to feel less discomfort when it is inserted in his/her ear, suppresses a peak that occurs when the minimum resonance frequency increases, freely adjusts the sound pressure frequency characteristics in the frequency range lower than the minimum resonance frequency, and is adaptable to various users who need different sound pressure frequency characteristics.

As described above, according to the present disclosure, even the earphone using the loudspeaker unit having the low minimum resonance frequency can provide the sound pressure frequency characteristics in which the frequency range lower than the minimum resonance frequency and the frequency range higher than the minimum resonance frequency are well balanced. Thereby, high sound quality can be achieved in earphones of hearing aids, portable music players, and the like.

## INDUSTRIAL APPLICABILITY

The earphone according to the present disclosure is applicable to AV equipment such as hearing aids, portable music players, and the like.

## DESCRIPTION OF THE REFERENCE CHARACTERS

**100**, **500**, **1000** earphone
**101**, **601** sound conductive tube
**102**, **602**, **1001** loudspeaker unit
**103**, **603**, **1002** housing
**104**, **604**, **804** yoke
**105**, **605**, **805** magnet
**106**, **606**, **806** plate
**107**, **607**, **807** sound hole
**108**, **608**, **808** support member
**109**, **609**, **809** diaphragm
**110**, **610**, **810** frame
**111**, **611**, **811** magnetic gap
**112**, **612**, **812** voice coil
**113**, **613**, **813** magnetic fluid
**114**, **614**, **814** first air hole
**115**, **615** first braking part
**116**, **616**, **816** second braking part
**119**, **619**, **819** third braking part
**501** ear chip
**502** terminal
**503** wires
**504** cord
**617** back surface plate
**618** second air hole
**901** receiver part
**902** hearing aid body
**903** lead tube
**1003** sound output hole
**1004** back surface panel

The invention claimed is:

**1**. An earphone, comprising:

a loudspeaker unit including a magnet, a yoke fixed to a back surface of the magnet, a plate having a back surface fixed to a front surface of the magnet, and a diaphragm disposed on a side of a front surface of the plate, a back surface of the diaphragm and the front surface of the plate having a first space formed therebetween;

a sound conductive tube which is connected to a back surface of the loudspeaker unit, the sound conductive tube having a hole connected to outside the earphone;

a sound hole penetrating the plate, the magnet, and the yoke, the sound hole and the hole in the sound conductive tube connecting the first space to outside the earphone;

a housing which is connected to a front surface of the loudspeaker unit, the housing and the front surface of the loudspeaker unit having a second space formed therebetween, and the housing being penetrated by a singlet air hole that connects the second space to outside the earphone;

a back surface plate, disposed inside the housing, dividing the second space into a space on a side of the loudspeaker unit and a space on a side of the single air hole, the back surface plate having another air hole that connects the space on the side of the loudspeaker unit to the space on the side of the single air hole;

a first braking member which closes the other air hole and is joined to the back surface plate; and

a second braking member which is joined to the housing to close the single air hole and to reduce the passing amount of sound.

**2**. The earphone according to claim **1**, wherein the loudspeaker unit further comprises:

a circular voice coil joined to the diaphragm; and

a magnetic fluid filling a third space between an inner peripheral surface of the voice coil and an outer peripheral surface of the plate, wherein

a magnetic gap is formed between the plate and the yoke, and

the voice coil is held in the magnetic gap.

**3**. The earphone according to claim **2**, wherein

the magnetic fluid fills the third space, so that the first space is partitioned by (i) the diaphragm, (ii) the voice coil, (iii) the magnetic fluid, and (iv) the plate, and

the sound hole and the sound conductive tube are connected to each other to form a third air hole, and the third air hole connects the first space to outside the earphone.

**4**. The earphone according to claim **3**, wherein the first space is partitioned only by (i) the diaphragm, (ii) the voice coil, (iii) the magnetic fluid, and (iv) the plate.

**5**. The earphone according to claim **1**, wherein

the first braking member and the second braking member are made of a nonwoven fabric or a woven fabric.

**6**. The earphone according to claim **1**, further comprising:

a third braking member which is provided on a loudspeaker unit side of the sound conductive tube, and closes the hole of the sound conductive tube.

* * * * *